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NOVEL BAKING ENZYME NBE 038 AND USES THEREOF

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NOVEL BAKING ENZYME NBE 038 AND USES THEREOF

5

**Field of the invention**

The invention relates to a newly identified polynucleotide sequence comprising a gene that encodes a novel baking enzyme. The invention features the full length nucleotide sequence of the novel gene, the cDNA sequence comprising the full  
10 length coding sequence of the novel baking enzyme as well as the amino acid sequence of the full-length functional protein and functional equivalents thereof. The invention also relates to methods of using these enzymes in industrial processes and methods of diagnosing fungal infections. Also included in the invention are cells transformed with a polynucleotide according to the invention and cells wherein a baking  
15 enzyme according to the invention is genetically modified to enhance its activity and/or level of expression.

**Background of the invention**

20

Baked products such as bread are prepared from a dough which is usually made from the basic ingredients (wheat) flour, water and optionally salt. Depending on the baked products, other ingredients added may be are sugars, flavours etceteras. For leavened products, primarily baker's yeast is used next to chemical leavening systems such as a combination of an acid (generating compound) and  
25 bicarbonate.

In order to improve the handling properties of the dough and/or the final properties of the baked products there is a continuous effort to develop processing aids with improving properties. Processing aids are defined herein as compounds that improve the handling properties of the dough and/or the final properties of the baked products.  
30 Dough properties that may be improved comprise machineability, gas retaining capability, reduced stickiness, elasticity, extensibility, moldability etcetera. Properties of the baked products that may be improved comprise loaf volume, crust crispiness, crumb texture and softness, flavour relative staleness and shelf life. These dough and/or baked product improving processing aids can be divided into two groups: chemical additives and  
35 enzymes.

Yeast, enzymes and chemical additives are generally added separately to the dough. Yeast may be added as a liquid suspension, in a compressed form or as

active dry (ADY) or instant dry yeast (IDY). The difference between these yeast formulations is the water- and yeast dry matter content. Liquid yeast has a yeast dry matter content of less than 25% (w/v). Cream yeast is a particular form of liquid yeast and has a dry matter content between 17 and 23% (w/v). Compressed yeast has a dry matter content between 25-35% (w/v) while the dry yeast formulations have a dry matter content between 92-98% (w/v).

Enzymes may be added in a dry, e.g. granulated form or in dissolved form. The chemical additives are in most cases added in powder form. Also, processing aid compositions which are tailored to specific baking applications, may be composed of a dedicated mixture of chemical additives and enzyme.

The preparation of a dough from the ingredients and processing aids described above is well known in the art and comprises mixing of said ingredients and processing aids and one or more moulding and fermentation steps.

The preparation of baked products from such doughs is also well known in the art and may comprise molding and shaping and further fermentation of the dough followed by baking at required temperatures and baking times.

Chemical additives with improving properties comprise oxidising agents such as ascorbic acid, bromate and azodicarbonate, reducing agents such as L-cysteine and glutathione, emulsifiers acting as dough conditioners such as diacetyl tartaric esters of mono/diglycerides (DATEM), sodium stearyl lactylate (SSL) or calcium stearyl lactylate (CSL), or acting as crumb softeners such as glycerol monostearate (GMS) etceteras, fatty materials such as triglycerides (fat) or lecithin and others.

As a result of a consumer-driven need to replace the chemical additives by more natural products, several enzymes have been developed with dough and/or baked product improving properties and which are used in all possible combinations depending on the specific baking application conditions. Suitable enzymes include starch degrading enzymes, arabinoxylan- and other hemicellulose degrading enzymes, cellulose degrading enzymes, oxidizing enzymes, fatty material splitting enzymes, protein degrading, modifying or crosslinking enzymes.

Starch degrading enzymes are for instance endo-acting enzymes such as alpha-amylase, maltogenic amylase, pullulanase or other debranching enzymes and exo-acting enzymes that cleave off glucose (amyloglucosidase), maltose (beta-amylase), maltotriose, maltotetraose and higher oligosaccharides.

Arabinoxylan- and other hemicellulose degrading enzymes are for instance xylanases, pentosanases, hemicellulase, arabinofuranosidase, glucanase and

others.

Cellulose degrading enzymes are for instance cellulase (beta-1,4-endoglucanase), cellobiohydrolase and beta-glucosidase.

5 Oxidizing enzymes are for instance glucose oxidase, hexose oxidase, pyranose oxidase, sulfhydryl oxidase, lipoxygenase, laccase, polyphenol oxidases and others.

Fatty material splitting enzymes are for instance triacylglycerol lipases, phospholipases (such as A<sub>1</sub>, A<sub>2</sub>, B, C and D) and galactolipases.

10 Protein degrading, modifying or crosslinking enzymes are for instance endo-acting proteases (serine proteases, metalloproteases, aspartyl proteases, thiol proteases), exo-acting peptidases that cleave off one amino acid, or dipeptide, tripeptide etceteras from the N-terminal (aminopeptidases) or C-terminal (carboxypeptidases) ends of the polypeptide chain, asparagines or glutamine deamidating enzymes such as deamidase and peptidoglutaminase or crosslinking enzymes such as transglutaminase.

15 Baking enzymes may conveniently be produced in microorganisms. Microbial baking enzymes are available from a variety of sources; *Bacillus spec.* are a common source of bacterial enzymes, whereas fungal enzymes are commonly produced in *Aspergillus spec.*

20 Baking enzymes may be used in a manifold of baked goods. The term "baked goods" is herein defined as to comprise bread products such as tin bread, loaves of bread, French bread as well as rolls, cakes, pies, muffins, yeast raised and cake doughnuts and the like.

25 In the above processes, it is advantageous to use baking enzymes that are obtained by recombinant DNA techniques. Such recombinant enzymes have a number of advantages over their traditionally purified counterparts. Recombinant enzymes may be produced at a low cost price, high yield, free from contaminating agents like bacteria or viruses but also free from bacterial toxins or contaminating other enzyme activities.

### **Object of the invention**

30

It is an object of the invention to provide novel polynucleotides encoding novel baking enzymes with improved properties. A further object is to provide naturally and recombinantly produced baking enzymes as well as recombinant strains producing these. Also fusion polypeptides are part of the invention as well as methods of making and using the polynucleotides and polypeptides according to the invention.

35

### **Summary of the invention**

The invention provides for novel polynucleotides encoding novel baking enzymes, in particular enzymes with Triacylglycerol lipase activity (E.C. Number 3.1.1.3).

More in particular, the invention provides for polynucleotides having a nucleotide sequence that hybridises preferably under highly stringent conditions to a sequence according to SEQ ID NO: 1 or SEQ ID NO: 2. Consequently, the invention provides nucleic acids that are more than 40% such as about 60%, preferably 65%, more preferably 70%, even more preferably 75%, 80%, 85%, 90%, 95%, 96%, 97%, 98% or 99% homologous to the sequences according to SEQ ID NO: 1 or SEQ ID NO: 2.

In a more preferred embodiment the invention provides for such an isolated polynucleotide obtainable from a filamentous fungus, in particular *A. niger* is preferred.

In one embodiment, the invention provides for an isolated polynucleotide comprising a nucleic acid sequence encoding a polypeptide with an amino acid sequence as shown in SEQ ID NO: 3 or functional equivalents thereof.

In a further preferred embodiment, the invention provides an isolated polynucleotide encoding at least one functional domain of a polypeptide according to SEQ ID NO: 3 or functional equivalents thereof.

In a preferred embodiment the invention provides a baking enzyme gene according to SEQ ID NO: 1. In another aspect the invention provides a polynucleotide, preferably a cDNA encoding an *A. niger* baking enzyme whose amino acid sequence is shown in SEQ ID NO: 3 or variants or fragments of that polypeptide. In a preferred embodiment the cDNA has a sequence according to SEQ ID NO: 2 or functional equivalents thereof.

In an even further preferred embodiment, the invention provides for a polynucleotide comprising the coding sequence of the polynucleotides according to the invention, preferred is the polynucleotide sequence of SEQ ID NO: 2.

The invention also relates to vectors comprising a polynucleotide sequence according to the invention and primers, probes and fragments that may be used to amplify or detect the DNA according to the invention.

In a further preferred embodiment, a vector is provided wherein the polynucleotide sequence according to the invention is functionally linked with regulatory sequences suitable for expression of the encoded amino acid sequence in a suitable

host cell, such as *A. niger* or *A. oryzae*. The invention also provides methods for preparing polynucleotides and vectors according to the invention.

The invention also relates to recombinantly produced host cells that contain heterologous or homologous polynucleotides according to the invention.

5 In another embodiment, the invention provides recombinant host cells wherein the expression of a baking enzyme according to the invention is significantly increased or wherein the activity of the baking enzyme is increased.

10 In another embodiment the invention provides for a recombinantly produced host cell that contains heterologous or homologous DNA according to the invention and wherein the cell is capable of producing a functional baking enzyme according to the invention, preferably a cell capable of over-expressing the baking enzyme according to the invention, for example an *Aspergillus* strain comprising an increased copy number of a gene or cDNA according to the invention.

15 In yet another aspect of the invention, a purified polypeptide is provided. The polypeptides according to the invention include the polypeptides encoded by the polynucleotides according to the invention. Especially preferred is a polypeptide according to SEQ ID NO: 3 or functional equivalents thereof.

20 Accordingly, in one aspect the present invention provides a baking enzyme composition containing as an active ingredient an enzyme according to SEQ ID NO: 3 or functional equivalents thereof.

In another aspect, the invention provides a method of making baked goods wherein there is incorporated into the dough used for making the baked goods an enzyme according to SEQ ID NO: 3 or functional equivalents thereof.

25 Fusion proteins comprising a polypeptide according to the invention are also within the scope of the invention. The invention also provides methods of making the polypeptides according to the invention.

The invention also relates to the use of the baking enzyme according to the invention in any industrial process as described herein

## 30 **Detailed description of the invention**

### **Polynucleotides**

35 The present invention provides polynucleotides encoding a baking enzyme, tentatively called NBE 038, having an amino acid sequence according to SEQ ID NO: 3 or functional equivalents thereof. The sequence of the gene encoding NBE

038 was determined by sequencing a genomic clone obtained from *Aspergillus niger*. The invention provides polynucleotide sequences comprising the gene encoding the NBE 038 baking enzyme as well as its complete cDNA sequence and its coding sequence. Accordingly, the invention relates to an isolated polynucleotide comprising  
5 the nucleotide sequence according to SEQ ID NO: 1 or SEQ ID NO: 2 or functional equivalents thereof.

More in particular, the invention relates to an isolated polynucleotide hybridisable under stringent conditions, preferably under highly stringent conditions, to a polynucleotide according to SEQ ID NO: 1 or SEQ ID NO: 2. Advantageously, such  
10 polynucleotides may be obtained from filamentous fungi, in particular from *Aspergillus niger*. More specifically, the invention relates to an isolated polynucleotide having a nucleotide sequence according to SEQ ID NO: 1 or SEQ ID NO: 2.

The invention also relates to an isolated polynucleotide encoding at least one functional domain of a polypeptide according to SEQ ID NO: 3 or functional  
15 equivalents thereof.

As used herein, the terms "gene" and "recombinant gene" refer to nucleic acid molecules which may be isolated from chromosomal DNA, which include an open reading frame encoding a protein, e.g. an *A. niger* baking enzyme. A gene may include coding sequences, non-coding sequences, introns and regulatory  
20 sequences. Moreover, a gene refers to an isolated nucleic acid molecule as defined herein.

A nucleic acid molecule of the present invention, such as a nucleic acid molecule having the nucleotide sequence of SEQ ID NO: 1 or SEQ ID NO: 2 or a functional equivalent thereof, can be isolated using standard molecular biology  
25 techniques and the sequence information provided herein. For example, using all or portion of the nucleic acid sequence of SEQ ID NO: 1 or the nucleotide sequence of SEQ ID NO: 2 as a hybridization probe, nucleic acid molecules according to the invention can be isolated using standard hybridization and cloning techniques (e. g., as described in Sambrook, J., Fritsh, E. F., and Maniatis, T. *Molecular Cloning: A*  
30 *Laboratory Manual*. 2nd, ed., Cold Spring Harbor Laboratory, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY, 1989).

Moreover, a nucleic acid molecule encompassing all or a portion of SEQ ID NO: 1 or SEQ ID NO: 2 can be isolated by the polymerase chain reaction (PCR) using synthetic oligonucleotide primers designed based upon the sequence  
35 information contained in SEQ ID NO:1 or SEQ ID NO: 2.

A nucleic acid of the invention can be amplified using cDNA, mRNA



or alternatively, genomic DNA, as a template and appropriate oligonucleotide primers according to standard PCR amplification techniques. The nucleic acid so amplified can be cloned into an appropriate vector and characterized by DNA sequence analysis.

Furthermore, oligonucleotides corresponding to or hybridisable to  
5 nucleotide sequences according to the invention can be prepared by standard synthetic techniques, e. g., using an automated DNA synthesizer.

In a preferred embodiment, an isolated nucleic acid molecule of the invention comprises the nucleotide sequence shown in SEQ ID NO: 2. The sequence of SEQ ID NO: 2 corresponds to the coding region of the A. niger NBE 038 cDNA. This  
10 cDNA comprises sequences encoding the A. niger NBE 038 polypeptide according to SEQ ID NO: 3.

In another preferred embodiment, an isolated nucleic acid molecule of the invention comprises a nucleic acid molecule which is a complement of the nucleotide sequence shown in SEQ ID NO:1 or SEQ ID NO: 2 or a functional  
15 equivalent of these nucleotide sequences.

A nucleic acid molecule which is complementary to another nucleotide sequence is one which is sufficiently complementary to the other nucleotide sequence such that it can hybridize to the other nucleotide sequence thereby forming a stable duplex.

20 One aspect of the invention pertains to isolated nucleic acid molecules that encode a polypeptide of the invention or a functional equivalent thereof such as a biologically active fragment or domain, as well as nucleic acid molecules sufficient for use as hybridisation probes to identify nucleic acid molecules encoding a polypeptide of the invention and fragments of such nucleic acid molecules suitable for  
25 use as PCR primers for the amplification or mutation of nucleic acid molecules.

An "isolated polynucleotide" or "isolated nucleic acid" is a DNA or RNA that is not immediately contiguous with both of the coding sequences with which it is immediately contiguous (one on the 5' end and one on the 3' end) in the naturally occurring genome of the organism from which it is derived. Thus, in one embodiment,  
30 an isolated nucleic acid includes some or all of the 5' non-coding (e.g., promotor) sequences that are immediately contiguous to the coding sequence. The term therefore includes, for example, a recombinant DNA that is incorporated into a vector, into an autonomously replicating plasmid or virus, or into the genomic DNA of a prokaryote or eukaryote, or which exists as a separate molecule (e.g., a cDNA or a  
35 genomic DNA fragment produced by PCR or restriction endonuclease treatment) independent of other sequences. It also includes a recombinant DNA that is part of a

hybrid gene encoding an additional polypeptide that is substantially free of cellular material, viral material, or culture medium (when produced by recombinant DNA techniques), or chemical precursors or other chemicals (when chemically synthesized). Moreover, an "isolated nucleic acid fragment" is a nucleic acid fragment that is not naturally occurring as a fragment and would not be found in the natural state.

5 As used herein, the terms "polynucleotide" or "nucleic acid molecule" are intended to include DNA molecules (e.g., cDNA or genomic DNA) and RNA molecules (e.g., mRNA) and analogs of the DNA or RNA generated using nucleotide analogs. The nucleic acid molecule can be single-stranded or double-stranded, but preferably is double-stranded DNA. The nucleic acid may be synthesized using  
10 oligonucleotide analogs or derivatives (e.g., inosine or phosphorothioate nucleotides). Such oligonucleotides can be used, for example, to prepare nucleic acids that have altered base-pairing abilities or increased resistance to nucleases.

Another embodiment of the invention provides an isolated nucleic acid molecule which is antisense to an NBE 038 nucleic acid molecule, e.g., the coding strand of an NBE 038 nucleic acid molecule. Also included within the scope of the invention are the complement strands of the nucleic acid molecules described herein.

### Sequencing errors

20

The sequence information as provided herein should not be so narrowly construed as to require inclusion of erroneously identified bases. The specific sequences disclosed herein can be readily used to isolate the complete gene from filamentous fungi, in particular *A. niger* which in turn can easily be subjected to further sequence analyses thereby identifying sequencing errors.

25

Unless otherwise indicated, all nucleotide sequences determined by sequencing a DNA molecule herein were determined using an automated DNA sequencer and all amino acid sequences of polypeptides encoded by DNA molecules determined herein were predicted by translation of a DNA sequence determined as  
30 above. Therefore, as is known in the art for any DNA sequence determined by this automated approach, any nucleotide sequence determined herein may contain some errors. Nucleotide sequences determined by automation are typically at least about 90% identical, more typically at least about 95% to at least about 99.9% identical to the actual nucleotide sequence of the sequenced DNA molecule. The actual sequence can  
35 be more precisely determined by other approaches including manual DNA sequencing methods well known in the art. As is also known in the art, a single insertion or deletion

in a determined nucleotide sequence compared to the actual sequence will cause a frame shift in translation of the nucleotide sequence such that the predicted amino acid sequence encoded by a determined nucleotide sequence will be completely different from the amino acid sequence actually encoded by the sequenced DNA molecule,  
5 beginning at the point of such an insertion or deletion.

The person skilled in the art is capable of identifying such erroneously identified bases and knows how to correct for such errors.

### **Nucleic acid fragments, probes and primers**

10

A nucleic acid molecule according to the invention may comprise only a portion or a fragment of the nucleic acid sequence shown in SEQ ID NO:1 or SEQ ID NO:2, for example a fragment which can be used as a probe or primer or a fragment encoding a portion of a NBE 038 protein. The nucleotide sequence determined from  
15 the cloning of the NBE 038 gene and cDNA allows for the generation of probes and primers designed for use in identifying and/or cloning other NBE 038 family members, as well as NBE 038 homologues from other species. The probe/primer typically comprises substantially purified oligonucleotide which typically comprises a region of nucleotide sequence that hybridizes preferably under highly stringent conditions to at  
20 least about 12 or 15, preferably about 18 or 20, preferably about 22 or 25, more preferably about 30, 35, 40, 45, 50, 55, 60, 65, or 75 or more consecutive nucleotides of a nucleotide sequence shown in SEQ ID NO:1 or SEQ ID NO: 2 or of a functional equivalent thereof.

Probes based on the NBE 038 nucleotide sequences can be used to  
25 detect transcripts or genomic NBE 038 sequences encoding the same or homologous proteins for instance in other organisms. In preferred embodiments, the probe further comprises a label group attached thereto, e.g., the label group can be a radioisotope, a fluorescent compound, an enzyme, or an enzyme cofactor. Such probes can also be used as part of a diagnostic test kit for identifying cells which express a NBE 038  
30 protein.

### **Identity & homology**

The terms "homology" or "percent identity" are used interchangeably  
35 herein. For the purpose of this invention, it is defined here that in order to determine the percent identity of two amino acid sequences or of two nucleic acid sequences, the

sequences are aligned for optimal comparison purposes (e.g., gaps can be introduced in the sequence of a first amino acid or nucleic acid sequence for optimal alignment with a second amino or nucleic acid sequence). The amino acid residues or nucleotides at corresponding amino acid positions or nucleotide positions are then compared. When a position in the first sequence is occupied by the same amino acid residue or nucleotide as the corresponding position in the second sequence, then the molecules are identical at that position. The percent identity between the two sequences is a function of the number of identical positions shared by the sequences (i.e., % identity = number of identical positions/total number of positions (i.e. overlapping positions) x 100). Preferably, the two sequences are the same length.

The skilled person will be aware of the fact that several different computer programmes are available to determine the homology between two sequences. For instance, a comparison of sequences and determination of percent identity between two sequences can be accomplished using a mathematical algorithm. In a preferred embodiment, the percent identity between two amino acid sequences is determined using the Needleman and Wunsch (J. Mol. Biol. (48):444-453 (1970)) algorithm which has been incorporated into the GAP program in the GCG software package (available at <http://www.gcg.com>), using either a Blossom 62 matrix or a PAM250 matrix, and a gap weight of 16, 14, 12, 10, 8, 6, or 4 and a length weight of 1, 2, 3, 4, 5, or 6. The skilled person will appreciate that all these different parameters will yield slightly different results but that the overall percentage identity of two sequences is not significantly altered when using different algorithms.

In yet another embodiment, the percent identity between two nucleotide sequences is determined using the GAP program in the GCG software package (available at <http://www.gcg.com>), using a NWSgapdna.CMP matrix and a gap weight of 40, 50, 60, 70, or 80 and a length weight of 1, 2, 3, 4, 5, or 6. In another embodiment, the percent identity two amino acid or nucleotide sequence is determined using the algorithm of E. Meyers and W. Miller (CABIOS, 4:11-17 (1989) which has been incorporated into the ALIGN program (version 2.0) (available at: <http://vega.igh.cnrs.fr/bin/align-guess.cgi>) using a PAM120 weight residue table, a gap length penalty of 12 and a gap penalty of 4.

The nucleic acid and protein sequences of the present invention can further be used as a "query sequence" to perform a search against public databases to, for example, identify other family members or related sequences. Such searches can be performed using the NBLAST and XBLAST programs (version 2.0) of Altschul, et al. (1990) J. Mol. Biol. 215:403—10. BLAST nucleotide searches can be performed with

the NBLAST program, score = 100, wordlength = 12 to obtain nucleotide sequences homologous to NBE 038 nucleic acid molecules of the invention. BLAST protein searches can be performed with the XBLAST program, score = 50, wordlength = 3 to obtain amino acid sequences homologous to NBE 038 protein molecules of the invention. To obtain gapped alignments for comparison purposes, Gapped BLAST can be utilized as described in Altschul et al., (1997) Nucleic Acids Res. 25(17):3389-3402. When utilizing BLAST and Gapped BLAST programs, the default parameters of the respective programs (e.g., XBLAST and NBLAST) can be used. See <http://www.ncbi.nlm.nih.gov>.

### **Hybridisation**

As used herein, the term "hybridizing" is intended to describe conditions for hybridization and washing under which nucleotide sequences at least about 50%, at least about 60%, at least about 70%, more preferably at least about 80%, even more preferably at least about 85% to 90%, more preferably at least 95% homologous to each other typically remain hybridized to each other.

A preferred, non-limiting example of such hybridization conditions are hybridization in 6X sodium chloride/sodium citrate (SSC) at about 45 °C, followed by one or more washes in 1 X SSC, 0.1 % SDS at 50 °C, preferably at 55 °C, preferably at 60 °C and even more preferably at 65 °C.

Highly stringent conditions include, for example, hybridizing at 68 °C in 5x SSC/5x Denhardt's solution / 1.0% SDS and washing in 0.2x SSC/0.1% SDS at room temperature. Alternatively, washing may be performed at 42 °C.

The skilled artisan will know which conditions to apply for stringent and highly stringent hybridisation conditions. Additional guidance regarding such conditions is readily available in the art, for example, in Sambrook et al., 1989, Molecular Cloning, A Laboratory Manual, Cold Spring Harbor Press, N.Y.; and Ausubel et al. (eds.), 1995, Current Protocols in Molecular Biology, (John Wiley & Sons, N.Y.).

Of course, a polynucleotide which hybridizes only to a poly A sequence (such as the 3' terminal poly(A) tract of mRNAs), or to a complementary stretch of T (or U) residues, would not be included in a polynucleotide of the invention used to specifically hybridize to a portion of a nucleic acid of the invention, since such a polynucleotide would hybridize to any nucleic acid molecule containing a poly (A) stretch or the complement thereof (e.g., practically any double-standed cDNA clone).

### **Obtaining full length DNA from other organisms**

5 In a typical approach, cDNA libraries constructed from other organisms, e.g. filamentous fungi, in particular from the species *Aspergillus* can be screened.

For example, *Aspergillus* strains can be screened for homologous NBE 038 polynucleotides by Northern blot analysis. Upon detection of transcripts homologous to polynucleotides according to the invention, cDNA libraries can be  
10 constructed from RNA isolated from the appropriate strain, utilizing standard techniques well known to those of skill in the art. Alternatively, a total genomic DNA library can be screened using a probe hybridisable to a NBE 038 polynucleotide according to the invention.

Homologous gene sequences can be isolated, for example, by  
15 performing PCR using two degenerate oligonucleotide primer pools designed on the basis of nucleotide sequences as taught herein.

The template for the reaction can be cDNA obtained by reverse transcription of mRNA prepared from strains known or suspected to express a polynucleotide according to the invention. The PCR product can be subcloned and  
20 sequenced to ensure that the amplified sequences represent the sequences of a new NBE 038 nucleic acid sequence, or a functional equivalent thereof.

The PCR fragment can then be used to isolate a full length cDNA clone by a variety of known methods. For example, the amplified fragment can be labeled and used to screen a bacteriophage or cosmid cDNA library. Alternatively, the  
25 labeled fragment can be used to screen a genomic library.

PCR technology also can be used to isolate full length cDNA sequences from other organisms. For example, RNA can be isolated, following standard procedures, from an appropriate cellular or tissue source. A reverse transcription reaction can be performed on the RNA using an oligonucleotide primer  
30 specific for the most 5' end of the amplified fragment for the priming of first strand synthesis.

The resulting RNA/DNA hybrid can then be "tailed" (e.g., with guanines) using a standard terminal transferase reaction, the hybrid can be digested with RNase H, and second strand synthesis can then be primed (e.g., with a poly-C  
35 primer). Thus, cDNA sequences upstream of the amplified fragment can easily be isolated. For a review of useful cloning strategies, see e.g., Sambrook et al., supra; and

Ausubel et al., supra.

Whether or not a homologous DNA fragment encodes a functional NBE 038 protein, may easily be tested by methods known in the art. Methods for testing enzyme activity of Triacylglycerol lipase s (E.C. number 3.1.1.3) may be found  
5 on <http://www.biochem.ucl.ac.uk/bsm/enzymes/>.

### Vectors

Another aspect of the invention pertains to vectors, preferably  
10 expression vectors, containing a nucleic acid encoding a NBE 038 protein or a functional equivalent thereof. As used herein, the term "vector" refers to a nucleic acid molecule capable of transporting another nucleic acid to which it has been linked. One type of vector is a "plasmid", which refers to a circular double stranded DNA loop into which additional DNA segments can be ligated. Another type of vector is a viral vector,  
15 wherein additional DNA segments can be ligated into the viral genome. Certain vectors are capable of autonomous replication in a host cell into which they are introduced (e.g., bacterial vectors having a bacterial origin of replication and episomal mammalian vectors). Other vectors (e.g., non-episomal mammalian vectors) are integrated into the genome of a host cell upon introduction into the host cell, and thereby are replicated  
20 along with the host genome. Moreover, certain vectors are capable of directing the expression of genes to which they are operatively linked. Such vectors are referred to herein as "expression vectors". In general, expression vectors of utility in recombinant DNA techniques are often in the form of plasmids. The terms "plasmid" and "vector" can be used interchangeably herein as the plasmid is the most commonly used form of  
25 vector. However, the invention is intended to include such other forms of expression vectors, such as viral vectors (e.g., replication defective retroviruses, adenoviruses and adeno-associated viruses), which serve equivalent functions.

The recombinant expression vectors of the invention comprise a nucleic acid of the invention in a form suitable for expression of the nucleic acid in a  
30 host cell, which means that the recombinant expression vector includes one or more regulatory sequences, selected on the basis of the host cells to be used for expression, which is operatively linked to the nucleic acid sequence to be expressed. Within a recombinant expression vector, "operatively linked" is intended to mean that the nucleotide sequence of interest is linked to the regulatory sequence(s) in a manner  
35 which allows for expression of the nucleotide sequence (e.g., in an *in vitro* transcription/translation system or in a host cell when the vector is introduced into the

host cell). The term "regulatory sequence" is intended to include promoters, enhancers and other expression control elements (e.g., polyadenylation signal). Such regulatory sequences are described, for example, in Goeddel; *Gene Expression Technology: Methods in Enzymology* 185, Academic Press, San Diego, CA (1990). Regulatory  
5 sequences include those which direct constitutive expression of a nucleotide sequence in many types of host cells and those which direct expression of the nucleotide sequence only in a certain host cell (e.g. tissue-specific regulatory sequences). It will be appreciated by those skilled in the art that the design of the expression vector can depend on such factors as the choice of the host cell to be transformed, the level of  
10 expression of protein desired, etc. The expression vectors of the invention can be introduced into host cells to thereby produce proteins or peptides, encoded by nucleic acids as described herein (e.g. NBE 038 proteins, mutant forms of NBE 038 proteins, fragments, variants or functional equivalents thereof, fusion proteins, etc.).

The recombinant expression vectors of the invention can be  
15 designed for expression of NBE 038 proteins in prokaryotic or eukaryotic cells. For example, NBE 038 proteins can be expressed in bacterial cells such as *E. coli*, insect cells (using baculovirus expression vectors) yeast cells or mammalian cells. Suitable host cells are discussed further in Goeddel, *Gene Expression Technology: Methods in Enzymology* 185, Academic Press, San Diego, CA (1990). Alternatively, the  
20 recombinant expression vector can be transcribed and translated *in vitro*, for example using T7 promoter regulatory sequences and T7 polymerase.

Expression vectors useful in the present invention include chromosomal-, episomal- and virus-derived vectors e.g., vectors derived from bacterial plasmids, bacteriophage, yeast episome, yeast chromosomal elements, viruses such  
25 as baculoviruses, papova viruses, vaccinia viruses, adenoviruses, fowl pox viruses, pseudorabies viruses and retroviruses, and vectors derived from combinations thereof, such as those derived from plasmid and bacteriophage genetic elements, such as cosmids and phagemids.

The DNA insert should be operatively linked to an appropriate  
30 promoter, such as the phage lambda PL promoter, the *E. coli* lac, trp and tac promoters, the SV40 early and late promoters and promoters of retroviral LTRs, to name a few. Other suitable promoters will be known to the skilled person. In a specific embodiment, promoters are preferred that are capable of directing a high expression level of baking enzymes in filamentous fungi. Such promoters are known in the art: The  
35 expression constructs may contain sites for transcription initiation, termination, and, in the transcribed region, a ribosome binding site for translation. The coding portion of the



mature transcripts expressed by the constructs will include a translation initiating AUG at the beginning and a termination codon appropriately positioned at the end of the polypeptide to be translated.

Vector DNA can be introduced into prokaryotic or eukaryotic cells via conventional transformation or transfection techniques. As used herein, the terms "transformation" and "transfection" are intended to refer to a variety of art-recognized techniques for introducing foreign nucleic acid (e.g., DNA) into a host cell, including calcium phosphate or calcium chloride co-precipitation, DEAE-dextran-mediated transfection, transduction, infection, lipofection, cationic lipid-mediated transfection or electroporation. Suitable methods for transforming or transfecting host cells can be found in Sambrook, et al. (*Molecular Cloning: A Laboratory Manual*, 2<sup>nd</sup>, ed. Cold Spring Harbor Laboratory, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY, 1989), Davis et al., *Basic Methods in Molecular Biology* (1986) and other laboratory manuals.

For stable transfection of mammalian cells, it is known that, depending upon the expression vector and transfection technique used, only a small fraction of cells may integrate the foreign DNA into their genome. In order to identify and select these integrants, a gene that encodes a selectable marker (e.g., resistance to antibiotics) is generally introduced into the host cells along with the gene of interest. Preferred selectable markers include those which confer resistance to drugs, such as G418, hygromycin and methotrexate. Nucleic acid encoding a selectable marker can be introduced into a host cell on the same vector as that encoding a NBE 038 protein or can be introduced on a separate vector. Cells stably transfected with the introduced nucleic acid can be identified by drug selection (e.g. cells that have incorporated the selectable marker gene will survive, while the other cells die).

Expression of proteins in prokaryotes is often carried out in *E. coli* with vectors containing constitutive or inducible promoters directing the expression of either fusion or non-fusion proteins. Fusion vectors add a number of amino acids to a protein encoded therein, e.g. to the amino terminus of the recombinant protein. Such fusion vectors typically serve three purposes: 1) to increase expression of recombinant protein; 2) to increase the solubility of the recombinant protein; and 3) to aid in the purification of the recombinant protein by acting as a ligand in affinity purification. Often, in fusion expression vectors, a proteolytic cleavage site is introduced at the junction of the fusion moiety and the recombinant protein to enable separation of the recombinant protein from the fusion moiety subsequent to purification of the fusion protein. Such enzymes, and their cognate recognition sequences, include Factor Xa,

thrombin and enterokinase.

As indicated, the expression vectors will preferably contain selectable markers. Such markers include dihydrofolate reductase or neomycin resistance for eukarotic cell culture and tetracycline or ampicilling resistance for culturing in *E. coli* and other bacteria. Representative examples of appropriate host include bacterial cells, such as *E. coli*, *Streptomyces* and *Salmonella typhimurium*; fungal cells, such as yeast; insect cells such as *Drosophila* S2 and *Spodoptera* Sf9; animal cells such as CHO, COS and Bowes melanoma; and plant cells. Appropriate culture mediums and conditions for the above-described host cells are known in the art.

Among vectors preferred for use in bacteria are pQE70, pQE60 and PQE-9, available from Qiagen; pBS vectors, Phagescript vectors, Bluescript vectors, pNH8A, pNH16A, pNH18A, pNH46A, available from Stratagene; and ptrc99a, pKK223-3, pKK233-3, pDR540, pRIT5 available from Pharmacia. Among preferred eukaryotic vectors are PWLNEO, pSV2CAT, pOG44, pZT1 and pSG available from Stratagene; and pSVK3, pBPV, pMSG and pSVL available from Pharmacia. Other suitable vectors will be readily apparent to the skilled artisan.

Among known bacterial promoters for use in the present invention include *E. coli* lacI and lacZ promoters, the T3 and T7 promoters, the gpt promoter, the lambda PR, PL promoters and the trp promoter, the HSV thymidine kinase promoter, the early and late SV40 promoters, the promoters of retroviral LTRs, such as those of the Rous sarcoma virus ("RSV"), and metallothionein promoters, such as the mouse metallothionein-I promoter.

Transcription of the DNA encoding the polypeptides of the present invention by higher eukaryotes may be increased by inserting an enhancer sequence into the vector. Enhancers are cis-acting elements of DNA, usually about from 10 to 300 bp that act to increase transcriptional activity of a promoter in a given host cell-type. Examples of enhancers include the SV40 enhancer, which is located on the late side of the replication origin at bp 100 to 270, the cytomegalovirus early promoter enhancer, the polyoma enhancer on the late side of the replication origin, and adenovirus enhancers.

For secretion of the translated protein into the lumen of the endoplasmic reticulum, into the periplasmic space or into the extracellular environment, appropriate secretion signal may be incorporated into the expressed polypeptide. The signals may be endogenous to the polypeptide or they may be heterologous signals.

The polypeptide may be expressed in a modified form, such as a fusion protein, and may include not only secretion signals but also additional

heterologous functional regions. Thus, for instance, a region of additional amino acids, particularly charged amino acids, may be added to the N-terminus of the polypeptide to improve stability and persistence in the host cell, during purification or during subsequent handling and storage. Also, peptide moieties may be added to the polypeptide to facilitate purification.

### **Polypeptides according to the invention**

The invention provides an isolated polypeptide having the amino acid sequence according to SEQ ID NO: 3, an amino acid sequence obtainable by expressing the polynucleotide of SEQ ID NO: 1 in an appropriate host, as well as an amino acid sequence obtainable by expressing the polynucleotide sequences of SEQ ID NO: 2 in an appropriate host. Also, a peptide or polypeptide comprising a functional equivalent of the above polypeptides is comprised within the present invention. The above polypeptides are collectively comprised in the term "polypeptides according to the invention"

The terms "peptide" and "oligopeptide" are considered synonymous (as is commonly recognized) and each term can be used interchangeably as the context requires to indicate a chain of at least two amino acids coupled by peptidyl linkages. The word "polypeptide" is used herein for chains containing more than seven amino acid residues. All oligopeptide and polypeptide formulas or sequences herein are written from left to right and in the direction from amino terminus to carboxy terminus. The one-letter code of amino acids used herein is commonly known in the art and can be found in Sambrook, et al. (*Molecular Cloning: A Laboratory Manual*, 2<sup>nd</sup>, ed. Cold Spring Harbor Laboratory, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY, 1989)

By "isolated" polypeptide or protein is intended a polypeptide or protein removed from its native environment. For example, recombinantly produced polypeptides and proteins expressed in host cells are considered isolated for the purpose of the invention as are native or recombinant polypeptides which have been substantially purified by any suitable technique such as, for example, the single-step purification method disclosed in Smith and Johnson, *Gene* 67:31-40 (1988).

The NBE 038 baking enzyme according to the invention can be recovered and purified from recombinant cell cultures by well-known methods including ammonium sulfate or ethanol precipitation, acid extraction, anion or cation exchange chromatography, phosphocellulose chromatography, hydrophobic interaction

chromatography, affinity chromatography, hydroxylapatite chromatography and lectin chromatography. Most preferably, high performance liquid chromatography ("HPLC") is employed for purification.

5 Polypeptides of the present invention include naturally purified products, products of chemical synthetic procedures, and products produced by recombinant techniques from a prokaryotic or eukaryotic host, including, for example, bacterial, yeast, higher plant, insect and mammalian cells. Depending upon the host employed in a recombinant production procedure, the polypeptides of the present invention may be glycosylated or may be non-glycosylated. In addition, polypeptides of  
10 the invention may also include an initial modified methionine residue, in some cases as a result of host-mediated processes.

A NBE 038 polypeptide according to the invention may be advantageously used in baking processes. The amount of enzyme to be added to the dough is determined empirically. It may depend on the quality of the flour used, the  
15 degree of improvement which is required, the kind of bread or baked goods, the method of preparing the dough, the proportion of other ingredients etcetera.

The effect of the addition of the NBE 038 enzyme according to the invention manifests itself in the physical properties of dough and the quality of the baked goods. By the addition of the enzyme, the dough has improved elasticity, is less  
20 sticky, and machinability is significantly improved. Also, the volume of the baked goods is increased, the crumb has a finer structure and a better softness is obtained. Staling of the bread is suppressed when a NBE 038 enzyme is added to the dough.

### Protein fragments

25

The invention also features biologically active fragments of the polypeptides according to the invention.

Biologically active fragments of a polypeptide of the invention include polypeptides comprising amino acid sequences sufficiently identical to or derived from  
30 the amino acid sequence of the NBE 038 protein (e.g., the amino acid sequence of SEQ ID NO: 3), which include fewer amino acids than the full length protein, and exhibit at least one biological activity of the corresponding full-length protein. Typically, biologically active fragments comprise a domain or motif with at least one activity of the NBE 038 protein. Preferred is a fragment with Triacylglycerol lipase activity.

35

A biologically active fragment of a protein of the invention can be a polypeptide which is, for example, 10, 25, 50, 100 or more amino acids in length.

Moreover, other biologically active portions, in which other regions of the protein are deleted, can be prepared by recombinant techniques and evaluated for one or more of the biological activities of the native form of a polypeptide of the invention.

5 The invention also features nucleic acid fragments which encode the above biologically active fragments of the NBE 038 protein.

### **Fusion proteins**

10 The proteins of the present invention or functional equivalents thereof, e.g., biologically active portions thereof, can be operatively linked to a non-NBE 038 polypeptide (e.g., heterologous amino acid sequences) to form fusion proteins. As used herein, a NBE 038 "chimeric protein" or "fusion protein" comprises a NBE 038 polypeptide operatively linked to a non-NBE 038 polypeptide. A "NBE 038 polypeptide" refers to a polypeptide having an amino acid sequence corresponding to  
15 NBE 038, whereas a "non-NBE 038 polypeptide" refers to a polypeptide having an amino acid sequence corresponding to a protein which is not substantially homologous to the NBE 038 protein, e.g., a protein which is different from the NBE 038 protein and which is derived from the same or a different organism. Within a NBE 038 fusion protein the NBE 038 polypeptide can correspond to all or a portion of a NBE 038  
20 protein. In a preferred embodiment, a NBE 038 fusion protein comprises at least one biologically active fragment of a NBE 038 protein. In another preferred embodiment, a NBE 038 fusion protein comprises at least two biologically active portions of a NBE 038 protein. Within the fusion protein, the term "operatively linked" is intended to indicate that the NBE 038 polypeptide and the non-NBE 038 polypeptide are fused in-frame to  
25 each other. The non-NBE 038 polypeptide can be fused to the N-terminus or C-terminus of the NBE 038 polypeptide.

For example, in one embodiment, the fusion protein is a GST-NBE 038 fusion protein in which the NBE 038 sequences are fused to the C-terminus of the GST sequences. Such fusion proteins can facilitate the purification of recombinant NBE  
30 038. In another embodiment, the fusion protein is a NBE 038 protein containing a heterologous signal sequence at its N-terminus. In certain host cells (e.g., mammalian and Yeast host cells), expression and/or secretion of NBE 038 can be increased through use of a heterologous signal sequence.

35 In another example, the gp67 secretory sequence of the baculovirus envelope protein can be used as a heterologous signal sequence (*Current Protocols in Molecular Biology*, Ausubel et al., eds., John Wiley & Sons, 1992). Other examples of

eukaryotic heterologous signal sequences include the secretory sequences of melittin and human placental alkaline phosphatase (Stratagene; La Jolla, California). In yet another example, useful prokaryotic heterologous signal sequences include the phoA secretory signal (Sambrook et al., *supra*) and the protein A secretory signal (Pharmacia Biotech; Piscataway, New Jersey).

5 A signal sequence can be used to facilitate secretion and isolation of a protein or polypeptide of the invention. Signal sequences are typically characterized by a core of hydrophobic amino acids which are generally cleaved from the mature protein during secretion in one or more cleavage events. Such signal peptides contain  
10 processing sites that allow cleavage of the signal sequence from the mature proteins as they pass through the secretory pathway. The signal sequence directs secretion of the protein, such as from a eukaryotic host into which the expression vector is transformed, and the signal sequence is subsequently or concurrently cleaved. The protein can then be readily purified from the extracellular medium by art recognized  
15 methods. Alternatively, the signal sequence can be linked to the protein of interest using a sequence which facilitates purification, such as with a GST domain. Thus, for instance, the sequence encoding the polypeptide may be fused to a marker sequence, such as a sequence encoding a peptide, which facilitates purification of the fused polypeptide. In certain preferred embodiments of this aspect of the invention, the  
20 marker sequence is a hexa-histidine peptide, such as the tag provided in a pQE vector (Qiagen, Inc.), among others, many of which are commercially available. As described in *Gentz et al, Proc. Natl. Acad. Sci. USA 86:821-824 (1989)*, for instance, hexa-histidine provides for convenient purification of the fusion protein. The HA tag is another peptide useful for purification which corresponds to an epitope derived of influenza  
25 hemagglutinin protein, which has been described by *Wilson et al., Cell 37:767 (1984)*, for instance.

Preferably, a NBE 038 chimeric or fusion protein of the invention is produced by standard recombinant DNA techniques. For example, DNA fragments coding for the different polypeptide sequences are ligated together in-frame in  
30 accordance with conventional techniques, for example by employing blunt-ended or stagger-ended termini for ligation, restriction enzyme digestion to provide for appropriate termini, filling-in of cohesive ends as appropriate, alkaline phosphatase treatment to avoid undesirable joining, and enzymatic ligation. In another embodiment, the fusion gene can be synthesized by conventional techniques including automated  
35 DNA synthesizers. Alternatively, PCR amplification of gene fragments can be carried out using anchor primers which give rise to complementary overhangs between two

consecutive gene fragments which can subsequently be annealed and reamplified to generate a chimeric gene sequence (see, for example, *Current Protocols in Molecular Biology*, eds. Ausubel *et al.* John Wiley & Sons: 1992). Moreover, many expression vectors are commercially available that already encode a fusion moiety (e.g, a GST polypeptide). A NBE 038-encoding nucleic acid can be cloned into such an expression  
5 vector such that the fusion moiety is linked in-frame to the NBE 038 protein.

### **Functional equivalents**

10 The terms "functional equivalents" and "functional variants" are used interchangeably herein. Functional equivalents of NBE 038 DNA are isolated DNA fragments that encode a polypeptide that exhibits a particular function of the NBE 038 *A. niger* baking enzyme as defined herein. A functional equivalent of a NBE 038 polypeptide according to the invention is a polypeptide that exhibits at least one  
15 function of an *A. niger* baking enzyme as defined herein. Functional equivalents therefore also encompass biologically active fragments.

Functional protein or polypeptide equivalents may contain only conservative substitutions of one or more amino acids of SEQ ID NO: 3 or substitutions, insertions or deletions of non-essential amino acids. Accordingly, a non-  
20 essential amino acid is a residue that can be altered in SEQ ID NO: 3 without substantially altering the biological function. For example, amino acid residues that are conserved among the NBE 038 proteins of the present invention, are predicted to be particularly unamenable to alteration. Furthermore, amino acids conserved among the NBE 038 proteins according to the present invention and other baking enzymes are not  
25 likely to be amenable to alteration.

The term "conservative substitution" is intended to mean that a substitution in which the amino acid residue is replaced with an amino acid residue having a similar side chain. These families are known in the art and include amino acids with basic side chains (e.g.lysine, arginine and hystidine), acidic side chains (e.g.  
30 aspartic acid, glutamic acid), uncharged polar side chains (e.g., glycine, asparagines, glutamine, serine, threonine, tyrosine, cysteine), non-polar side chains (e.g., alanine, valine, leucine, isoleucine, proline, phenylalanine, methionine, tryptophan), beta-branched side chains (e.g., threonine, valine, isoleucine) and aromatic side chains (e.g., tyrosine, phenylalanine tryptophan, histidine).

35 Functional nucleic acid equivalents may typically contain silent mutations or mutations that do not alter the biological function of encoded polypeptide.

Accordingly, the invention provides nucleic acid molecules encoding NBE 038 proteins that contain changes in amino acid residues that are not essential for a particular biological activity. Such NBE 038 proteins differ in amino acid sequence from SEQ ID NO: 3 yet retain at least one biological activity. In one embodiment the isolated nucleic acid molecule comprises a nucleotide sequence encoding a protein, wherein the protein comprises a substantially homologous amino acid sequence of at least about 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or more homologous to the amino acid sequence shown in SEQ ID NO: 3.

For example, guidance concerning how to make phenotypically silent amino acid substitutions is provided in Bowie, J.U. et al., Science 247:1306-1310 (1990) wherein the authors indicate that there are two main approaches for studying the tolerance of an amino acid sequence to change. The first method relies on the process of evolution, in which mutations are either accepted or rejected by natural selection. The second approach uses genetic engineering to introduce amino acid changes at specific positions of a cloned gene and selects or screens to identify sequences that maintain functionality. As the authors state, these studies have revealed that proteins are surprisingly tolerant of amino acid substitutions. The authors further indicate which changes are likely to be permissive at a certain position of the protein. For example, most buried amino acid residues require non-polar side chains, whereas few features of surface side chains are generally conserved. Other such phenotypically silent substitutions are described in Bowie et al, supra, and the references cited therein.

An isolated nucleic acid molecule encoding a NBE 038 protein homologous to the protein according to SEQ ID NO: 3 can be created by introducing one or more nucleotide substitutions, additions or deletions into the coding nucleotide sequences according to SEQ ID NO: 1 or SEQ ID NO: 2 such that one or more amino acid substitutions, deletions or insertions are introduced into the encoded protein. Such mutations may be introduced by standard techniques, such as site-directed mutagenesis and PCR-mediated mutagenesis.

The term "functional equivalents" also encompasses orthologues of the A. niger NBE 038 protein. Orthologues of the A. niger NBE 038 protein are proteins that can be isolated from other strains or species and possess a similar or identical biological activity. Such orthologues can readily be identified as comprising an amino acid sequence that is substantially homologous to SEQ ID NO: 3.

As defined herein, the term "substantially homologous" refers to a first amino acid or nucleotide sequence which contains a sufficient or minimum number



of identical or equivalent (e.g., with similar side chain) amino acids or nucleotides to a second amino acid or nucleotide sequence such that the first and the second amino acid or nucleotide sequences have a common domain. For example, amino acid or nucleotide sequences which contain a common domain having about 60%, preferably 5 65%, more preferably 70%, even more preferably 75%, 80%, 85%, 90%, 95%, 96%, 97%, 98% or 99% identity or more are defined herein as sufficiently identical.

Also, nucleic acids encoding other NBE 038 family members, which thus have a nucleotide sequence that differs from SEQ ID NO: 1 or SEQ ID NO: 2, are within the scope of the invention. Moreover, nucleic acids encoding NBE 038 proteins 10 from different species which thus have a nucleotide sequence which differs from SEQ ID NO: 1 or SEQ ID NO: 2 are within the scope of the invention.


Nucleic acid molecules corresponding to variants (e.g. natural allelic variants) and homologues of the NBE 038 DNA of the invention can be isolated based on their homology to the NBE 038 nucleic acids disclosed herein using the cDNAs 15 disclosed herein or a suitable fragment thereof, as a hybridisation probe according to standard hybridisation techniques preferably under highly stringent hybridisation conditions.

In addition to naturally occurring allelic variants of the NBE 038 sequence, the skilled person will recognise that changes can be introduced by mutation 20 into the nucleotide sequences of SEQ ID NO: 1 or SEQ ID NO: 2 thereby leading to changes in the amino acid sequence of the NBE 038 protein without substantially altering the function of the NBE 038 protein.

In another aspect of the invention, improved NBE 038 proteins are provided. Improved NBE 038 proteins are proteins wherein at least one biological 25 activity is improved. Such proteins may be obtained by randomly introducing mutations along all or part of the NBE 038 coding sequence, such as by saturation mutagenesis, and the resulting mutants can be expressed recombinantly and screened for biological activity. For instance, the art provides for standard assays for measuring the enzymatic activity of baking enzymes and thus improved proteins may easily be selected.

30 In a preferred embodiment the NBE 038 protein has an amino acid sequence according to SEQ ID NO: 3. In another embodiment, the NBE 038 polypeptide is substantially homologous to the amino acid sequence according to SEQ ID NO: 3 and retains at least one biological activity of a polypeptide according to SEQ ID NO: 3, yet differs in amino acid sequence due to natural variation or mutagenesis as 35 described above.

In a further preferred embodiment, the NBE 038 protein has an amino



acid sequence encoded by an isolated nucleic acid fragment capable of hybridising to a nucleic acid according to SEQ ID NO: 1 or SEQ ID NO: 2, preferably under highly stringent hybridisation conditions.

Accordingly, the NBE 038 protein is a protein which comprises an amino acid sequence at least about 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or more homologous to the amino acid sequence shown in SEQ ID NO: 3 and retains at least one functional activity of the polypeptide according to SEQ ID NO: 3.

Functional equivalents of a protein according to the invention can also be identified e.g. by screening combinatorial libraries of mutants, e.g. truncation mutants, of the protein of the invention for baking enzyme activity. In one embodiment, a variegated library of variants is generated by combinatorial mutagenesis at the nucleic acid level. A variegated library of variants can be produced by, for example, enzymatically ligating a mixture of synthetic oligonucleotides into gene sequences such that a degenerate set of potential protein sequences is expressible as individual polypeptides, or alternatively, as a set of larger fusion proteins (e.g., for phage display). There are a variety of methods that can be used to produce libraries of potential variants of the polypeptides of the invention from a degenerate oligonucleotide sequence. Methods for synthesizing degenerate oligonucleotides are known in the art (see, e.g., Narang (1983) Tetrahedron 39:3; Itakura et al. (1984) Annu. Rev. Biochem. 53:323; Itakura et al. (1984) Science 198:1056; Ike et al. (1983) Nucleic Acid Res. 11:477).

In addition, libraries of fragments of the coding sequence of a polypeptide of the invention can be used to generate a variegated population of polypeptides for screening a subsequent selection of variants. For example, a library of coding sequence fragments can be generated by treating a double stranded PCR fragment of the coding sequence of interest with a nuclease under conditions wherein nicking occurs only about once per molecule, denaturing the double stranded DNA, renaturing the DNA to form double stranded DNA which can include sense/antisense pairs from different nicked products, removing single stranded portions from reformed duplexes by treatment with S1 nuclease, and ligating the resulting fragment library into an expression vector. By this method, an expression library can be derived which encodes N-terminal and internal fragments of various sizes of the protein of interest.

Several techniques are known in the art for screening gene products of combinatorial libraries made by point mutations of truncation, and for screening cDNA libraries for gene products having a selected property. The most widely used

techniques, which are amenable to high through-put analysis, for screening large gene libraries typically include cloning the gene library into replicable expression vectors, transforming appropriate cells with the resulting library of vectors, and expressing the combinatorial genes under conditions in which detection of a desired activity facilitates  
5 isolation of the vector encoding the gene whose product was detected. Recursive ensemble mutagenesis (REM), a technique which enhances the frequency of functional mutants in the libraries, can be used in combination with the screening assays to identify variants of a protein of the invention (Arkin and Yourvan (1992) Proc. Natl. Acad. Sci. USA 89:7811-7815; Delgrave et al. (1993) Protein Engineering  
10 6(3):327-331).

In addition to the NBE 038 gene sequence shown in SEQ ID NO: 1, it will be apparent for the person skilled in the art that DNA sequence polymorphisms that may lead to changes in the amino acid sequence of the NBE 038 protein may exist within a given population. Such genetic polymorphisms may exist in cells from different  
15 populations or within a population due to natural allelic variation. Allelic variants may also include functional equivalents.

Fragments of a polynucleotide according to the invention may also comprise polynucleotides not encoding functional polypeptides. Such polynucleotides may function as probes or primers for a PCR reaction.

20 Nucleic acids according to the invention irrespective of whether they encode functional or non-functional polypeptides, can be used as hybridization probes or polymerase chain reaction (PCR) primers. Uses of the nucleic acid molecules of the present invention that do not encode a polypeptide having a NBE 038 activity include, inter alia, (1) isolating the gene encoding the NBE 038 protein, or allelic variants  
25 thereof from a cDNA library e.g. from other organisms than *A. niger*; (2) in situ hybridization (e.g. FISH) to metaphase chromosomal spreads to provide precise chromosomal location of the NBE 038 gene as described in Verma et al., Human Chromosomes: a Manual of Basic Techniques, Pergamon Press, New York (1988); (3) Northern blot analysis for detecting expression of NBE 038 mRNA in specific tissues  
30 and/or cells and 4) probes and primers that can be used as a diagnostic tool to analyse the presence of a nucleic acid hybridisable to the NBE 038 probe in a given biological (e.g. tissue) sample.

Also encompassed by the invention is a method of obtaining a functional equivalent of a NBE 038 gene or cDNA. Such a method entails obtaining a  
35 labelled probe that includes an isolated nucleic acid which encodes all or a portion of the sequence according to SEQ ID NO: 3 or a variant thereof; screening a nucleic acid

fragment library with the labelled probe under conditions that allow hybridisation of the probe to nucleic acid fragments in the library, thereby forming nucleic acid duplexes, and preparing a full-length gene sequence from the nucleic acid fragments in any labelled duplex to obtain a gene related to the NBE 038 gene.

5                   In one embodiment, a NBE 038 nucleic acid of the invention is at least 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or more homologous to a nucleic acid sequence shown in SEQ ID NO: 1, SEQ ID NO: 2 or the complement thereof.

10                   In another preferred embodiment a NBE 038 polypeptide of the invention is at least 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or more homologous to the amino acid sequence shown in SEQ ID NO: 3.

#### **Host cells**

15                   In another embodiment, the invention features cells, e.g., transformed host cells or recombinant host cells that contain a nucleic acid encompassed by the invention. A "transformed cell" or "recombinant cell" is a cell into which (or into an ancestor of which) has been introduced, by means of recombinant DNA techniques, a  
20                   nucleic acid according to the invention. Both prokaryotic and eukaryotic cells are included, e.g., bacteria, fungi, yeast, and the like, especially preferred are cells from filamentous fungi, in particular *Aspergillus niger*.

                  A host cell can be chosen that modulates the expression of the inserted sequences, or modifies and processes the gene product in a specific, desired  
25                   fashion. Such modifications (e.g., glycosylation) and processing (e.g., cleavage) of protein products may facilitate optimal functioning of the protein.

                  Various host cells have characteristic and specific mechanisms for post-translational processing and modification of proteins and gene products.  
...               Appropriate cell lines or host systems familiar to those of skill in the art of molecular  
30                   biology and/or microbiology can be chosen to ensure the desired and correct modification and processing of the foreign protein expressed. To this end, eukaryotic host cells that possess the cellular machinery for proper processing of the primary transcript, glycosylation, and phosphorylation of the gene product can be used. Such host cells are well known in the art.

35                   Host cells also include, but are not limited to, mammalian cell lines such as CHO, VERO, BHK, HeLa, COS, MDCK, 293, 3T3, WI38, and choroid plexus

cell lines.

If desired, the polypeptides according to the invention can be produced by a stably-transfected cell line. A number of vectors suitable for stable transfection of mammalian cells are available to the public, methods for constructing such cell lines are also publicly known, e.g., in Ausubel et al. (supra).

### **Antibodies**

The invention further features antibodies, such as monoclonal or polyclonal antibodies, that specifically bind NBE 038 proteins according to the invention.

As used herein, the term "antibody" (Ab) or "monoclonal antibody" (Mab) is meant to include intact molecules as well as antibody fragments (such as, for example, Fab and F(ab')<sub>2</sub> fragments) which are capable of specifically binding to NBE 038 protein. Fab and F(ab')<sub>2</sub> fragments lack the Fc fragment of intact antibody, clear more rapidly from the circulation, and may have less non-specific tissue binding of an intact antibody (Wahl et al., *J. Nucl. Med.* 24:316-325 (1983)). Thus, these fragments are preferred.

The antibodies of the present invention may be prepared by any of a variety of methods. For example, cells expressing the NBE 038 protein or an antigenic fragment thereof can be administered to an animal in order to induce the production of sera containing polyclonal antibodies. In a preferred method, a preparation of NBE 038 protein is prepared and purified to render it substantially free of natural contaminants. Such a preparation is then introduced into an animal in order to produce polyclonal antisera of greater specific activity.

In the most preferred method, the antibodies of the present invention are monoclonal antibodies (or NBE 038 protein binding fragments thereof). Such monoclonal antibodies can be prepared using hybridoma technology (Kohler et al., *Nature* 256:495 (1975); Kohler et al., *Eur. J. Immunol.* 6:511 (1976); Hammerling et al., In: *Monoclonal Antibodies and T-Cell Hybridomas*, Elsevier, N.Y., pp. 563-681 (1981)). In general, such procedures involve immunizing an animal (preferably a mouse) with a NBE 038 protein antigen or, with a NBE 038 protein expressing cell. The splenocytes of such mice are extracted and fused with a suitable myeloma cell line. Any suitable myeloma cell line may be employed in accordance with the present invention; however, it is preferably to employ the parent myeloma cell line (SP<sub>2</sub>O), available from the American Type Culture Collection, Rockville, Maryland. After fusion, the resulting

hybridoma cells are selectively maintained in HAT medium, and then cloned by limiting dilution as described by Wands *et al.* (*Gastro-enterology* 80:225-232 (1981)). The hybridoma cells obtained through such a selection are then assayed to identify clones which secrete antibodies capable of binding the NBE 038 protein antigen. In general, the polypeptides can be coupled to a carrier protein, such as KLH, as described in Ausubel *et al.*, supra, mixed with an adjuvant, and injected into a host mammal.

In particular, various host animals can be immunized by injection of a polypeptide of interest. Examples of suitable host animals include rabbits, mice, guinea pigs, and rats. Various adjuvants can be used to increase the immunological response, depending on the host species, including but not limited to Freund's (complete and incomplete), adjuvant mineral gels such as aluminum hydroxide, surface active substances such as lysolecithin, pluronic polyols, polyanions, peptides, oil emulsions, keyhole limpet hemocyanin, dinitrophenol, BCG (bacille Calmette-Guerin) and *Corynebacterium parvum*. Polyclonal antibodies are heterogeneous populations of antibody molecules derived from the sera of the immunized animals.

Such antibodies can be of any immunoglobulin class including IgG, IgM, IgE, IgA, IgD, and any subclass thereof. The hybridomas producing the mAbs of this invention can be cultivated *in vitro* or *in vivo*.

Once produced, polyclonal or monoclonal antibodies are tested for specific recognition of a NBE 038 polypeptide or functional equivalent thereof in an immunoassay, such as a Western blot or immunoprecipitation analysis using standard techniques, e.g., as described in Ausubel *et al.*, supra. Antibodies that specifically bind to NBE 038 proteins or functional equivalents thereof are useful in the invention. For example, such antibodies can be used in an immunoassay to detect NBE 038 in pathogenic or non-pathogenic strains of *Aspergillus* (e.g., in *Aspergillus* extracts).

Preferably, antibodies of the invention are produced using fragments of the NBE 038 polypeptides that appear likely to be antigenic, by criteria such as high frequency of charged residues. For example, such fragments may be generated by standard techniques of PCR, and then cloned into the pGEX expression vector (Ausubel *et al.*, supra). Fusion proteins may then be expressed in *E. coli* and purified using a glutathione agarose affinity matrix as described in Ausubel, *et al.*, supra. If desired, several (e.g., two or three) fusions can be generated for each protein, and each fusion can be injected into at least two rabbits. Antisera can be raised by injections in a series, typically including at least three booster injections. Typically, the antisera are checked for their ability to immunoprecipitate a recombinant NBE 038 polypeptide or functional equivalents thereof whereas unrelated proteins may serve as

a control for the specificity of the immune reaction.

Alternatively, techniques described for the production of single chain antibodies (U.S. Patent 4,946,778 and 4,704,692) can be adapted to produce single chain antibodies against a NBE 038 polypeptide or functional equivalents thereof. Kits  
5 for generating and screening phage display libraries are commercially available e.g. from Pharmacia.

Additionally, examples of methods and reagents particularly amenable for use in generating and screening antibody display library can be found in, for example, U.S. Patent No. 5,223, 409; PCT Publication No. WO 92/18619; PCT  
10 Publication No. WO 91/17271; PCT Publication No. WO 20791; PCT Publication No. WO 92/20791; PCT Publication No. WO 92/15679; PCT Publication No. WO 93/01288; PCT Publication No. WO 92/01047; PCT Publication No. WO 92/09690; PCT Publication No. WO 90/02809; Fuchs et al. (1991) *Bio/Technology* 9:1370-1372; Hay et al. (1992) *Hum. Antibod. Hybridomas* 3:81-85; Huse et al. (1989) *Science*  
15 246;1275-1281; Griffiths et al. (1993) *EMBO J.* 12:725-734.

Polyclonal and monoclonal antibodies that specifically bind NBE 038 polypeptides of functional equivalents thereof can be used, for example, to detect expression of a NBE 038 gene or a functional equivalent thereof e.g. in another strain of *Aspergillus*. For example, NBE 038 polypeptide can be readily detected in  
20 conventional immunoassays of *Aspergillus* cells or extracts. Examples of suitable assays include, without limitation, Western blotting, ELISAs, radioimmune assays, and the like.

By "specifically binds" is meant that an antibody recognizes and binds a particular antigen, e.g., a NBE 038 polypeptide, but does not substantially  
25 recognize and bind other unrelated molecules in a sample.

Antibodies can be purified, for example, by affinity chromatography methods in which the polypeptide antigen is immobilized on a resin.

An antibody directed against a polypeptide of the invention (e.g., monoclonal antibody) can be used to isolate the polypeptide by standard techniques,  
30 such as affinity chromatography or immunoprecipitation. Moreover, such an antibody can be used to detect the protein (e.g., in a cellular lysate or cell supernatant) in order to evaluate the abundance and pattern of expression of the polypeptide. The antibodies can also be used diagnostically to monitor protein levels in cells or tissue as part of a clinical testing procedure, e.g., to, for example, determine the efficacy of a given  
35 treatment regimen or in the diagnosis of Aspergillosis..

Detection can be facilitated by coupling the antibody to a detectable

substance. Examples of detectable substances include various enzymes, prosthetic groups, fluorescent materials, luminescent materials, bioluminescent materials, and radioactive materials. Examples of suitable enzymes include horseradish peroxidase, alkaline phosphatase,  $\beta$ -galactosidase, or acetylcholinesterase; examples of suitable  
5 fluorescent materials include umbelliferone, fluorescein, fluorescein isothiocyanate, rhodamine, dichlorotriazinylamine fluorescein, dansyl chloride or phycoerythrin; an example of a luminescent material includes luminol; examples of bioluminescent materials include luciferase, luciferin, and aequorin, and examples of suitable radioactive materials include  $^{125}\text{I}$ ,  $^{131}\text{I}$ ,  $^{35}\text{S}$  or  $^3\text{H}$ .

10 Preferred epitopes encompassed by the antigenic peptide are regions that are located on the surface of the protein, e.g., hydrophilic regions. Hydrophobicity plots of the proteins of the invention can be used to identify hydrophilic regions.

The antigenic peptide of a protein of the invention comprises at least  
15 7 (preferably 10, 15, 20, or 30) contiguous amino acid residues of the amino acid sequence of SEQ ID NO: 3 and encompasses an epitope of the protein such that an antibody raised against the peptide forms a specific immune complex with the protein.

Preferred epitopes encompassed by the antigenic peptide are  
20 regions of NBE 038 that are located on the surface of the protein, e.g., hydrophilic regions, hydrophobic regions, alpha regions, beta regions; coil regions, turn regions and flexible regions.

### Immunoassays

25 Qualitative or quantitative determination of a polypeptide according to the present invention in a biological sample can occur using any art-known method. Antibody-based techniques provide special advantages for assaying specific polypeptide levels in a biological sample.

In these, the specific recognition is provided by the primary antibody  
30 (polyclonal or monoclonal) but the secondary detection system can utilize fluorescent, enzyme, or other conjugated secondary antibodies. As a result, an immunocomplex is obtained.

Accordingly, the invention provides a method for diagnosing whether a certain organism is infected with *Aspergillus* comprising the steps of:

- 35
- Isolating a biological sample from said organism suspected to be infected with *Aspergillus*,



- reacting said biological sample with an antibody according to the invention,
- determining whether immunocomplexes are formed.

5 Tissues can also be extracted, e.g., with urea and neutral detergent, for the liberation of protein for Western-blot or dot/slot assay. This technique can also be applied to body fluids.

Other antibody-based methods useful for detecting NBE 038 gene expression include immunoassays, such as the enzyme linked immunosorbent assay (ELISA) and the radioimmunoassay (RIA). For example, NBE 038-specific monoclonal antibodies can be used both as an immunoabsorbent and as an enzyme-labeled probe  
10 to detect and quantify the NBE 038 protein. The amount of NBE 038 protein present in the sample can be calculated by reference to the amount present in a standard preparation using a linear regression computer algorithm. In another ELISA assay, two distinct specific monoclonal antibodies can be used to detect NBE 038 protein in a biological fluid. In this assay, one of the antibodies is used as the immuno-absorbent  
15 and the other as the enzyme-labeled probe.

The above techniques may be conducted essentially as a "one-step" or "two-step" assay. The "one-step" assay involves contacting NBE 038 protein with immobilized antibody and, without washing, contacting the mixture with the labeled antibody. The "two-step" assay involves washing before contacting the mixture with the  
20 labeled antibody. Other conventional methods may also be employed as suitable. It is usually desirable to immobilize one component of the assay system on a support, thereby allowing other components of the system to be brought into contact with the component and readily removed from the sample.

Suitable enzyme labels include, for example, those from the oxidase  
25 group, which catalyze the production of hydrogen peroxide by reacting with substrate. Activity of an oxidase label may be assayed by measuring the concentration of hydrogen peroxide formed by the enzyme-labelled antibody/substrate reaction.

Besides enzymes, other suitable labels include radioisotopes, such as Iodine ( $^{125}\text{I}$ ,  $^{127}\text{I}$ ), carbon ( $^{14}\text{C}$ ), sulphur ( $^{35}\text{S}$ ), tritium ( $^3\text{H}$ ), indium ( $^{112}\text{In}$ ), and  
30 technetium ( $^{99\text{m}}\text{Tc}$ ), and fluorescent labels, such as fluorescein and rhodamine, and biotin.

Specific binding of a test compound to a NBE 038 polypeptide can be detected, for example, in vitro by reversibly or irreversibly immobilizing the NBE 038 polypeptide on a substrate, e.g., the surface of a well of a 96-well polystyrene microtitre  
35 plate. Methods for immobilizing polypeptides and other small molecules are well known

in the art. For example, the microtitre plates can be coated with a NBE 038 polypeptide by adding the polypeptide in a solution (typically, at a concentration of 0.05 to 1 mg/ml in a volume of 1-100 ul) to each well, and incubating the plates at room temperature to 37 °C for 0.1 to 36 hours. Polypeptides that are not bound to the plate can be removed  
5 by shaking the excess solution from the plate, and then washing the plate (once or repeatedly) with water or a buffer. Typically, the polypeptide is contained in water or a buffer. The plate is then washed with a buffer that lacks the bound polypeptide. To block the free protein-binding sites on the plates, the plates are blocked with a protein that is unrelated to the bound polypeptide. For example, 300 ul of bovine serum  
10 albumin (BSA) at a concentration of 2 mg/ml in Tris-HCl is suitable. Suitable substrates include those substrates that contain a defined cross-linking chemistry (e.g., plastic substrates, such as polystyrene, styrene, or polypropylene substrates from Corning Costar Corp. (Cambridge, MA), for example) . If desired, a beaded particle, e.g., beaded agarose or beaded sepharose, can be used as the substrate.

15 Binding of the test compound to the polypeptides according to the invention can be detected by any of a variety of artknown methods. For example, a specific antibody can be used in an immunoassay. If desired, the antibody can be labeled (e.g., fluorescently or with a radioisotope) and detected directly (see, e.g., West and McMahon, J. Cell Biol. 74:264, 1977). Alternatively, a second antibody can be  
20 used for detection (e.g., a labeled antibody that binds the Fc portion of an anti-AN97 antibody). In an alternative detection method, the NBE 038 polypeptide is labeled, and the label is detected (e.g., by labeling a NBE 038 polypeptide with a radioisotope, fluorophore, chromophore, or the like). In still another method, the NBE 038 polypeptide is produced as a fusion protein with a protein that can be detected  
25 optically, e.g., green fluorescent protein (which can be detected under UV light). In an alternative method, the NBE 038 polypeptide can be covalently attached to or fused with an enzyme having a detectable enzymatic activity, such as horse radish peroxidase, alkaline phosphatase,  $\alpha$ -galactosidase, or glucose oxidase. Genes encoding all of these enzymes have been cloned and are readily available for use by  
30 those of skill in the art. If desired, the fusion protein can include an antigen, and such an antigen can be detected and measured with a polyclonal or monoclonal antibody using conventional methods. Suitable antigens include enzymes (e.g., horse radish peroxidase, alkaline phosphatase, and  $\alpha$ -galactosidase) and non-enzymatic polypeptides (e.g., serum proteins, such as BSA and globulins, and milk proteins, such  
35 as caseins).

**Epitopes, antigens and immunogens.**

In another aspect, the invention provides a peptide or polypeptide comprising an epitope-bearing portion of a polypeptide of the invention. The epitope of this polypeptide portion is an immunogenic or antigenic epitope of a polypeptide of the invention. An "immunogenic epitope" is defined as a part of a protein that elicits an antibody response when the whole protein is the immunogen. These immunogenic epitopes are believed to be confined to a few loci on the molecule. On the other hand, a region of a protein molecule to which an antibody can bind is defined as an "antigenic epitope." The number of immunogenic epitopes of a protein generally is less than the number of antigenic epitopes. See, for instance, Geysen, H. M. et al., Proc. Natl. Acad. Sci. USA 81:3998-4002 (1984).

As to the selection of peptides or polypeptides bearing an antigenic epitope (i.e., that contain a region of a protein molecule to which an antibody can bind), it is well known in that art that relatively short synthetic peptides that mimic part of a protein sequence are routinely capable of eliciting an antiserum that reacts with the partially mimicked protein. See, for instance, Sutcliffe, J. G. et al., Science 219:660-666 (1984). Peptides capable of eliciting protein-reactive sera are frequently represented in the primary sequence of a protein, can be characterized by a set of simple chemical rules, and are confined neither to immunodominant regions of intact proteins (i.e., immunogenic epitopes) nor to the amino or carboxyl terminals. Peptides that are extremely hydrophobic and those of six or fewer residues generally are ineffective at inducing antibodies that bind to the mimicked protein; longer, soluble peptides, especially those containing proline residues, usually are effective. Sutcliffe et al., supra, at 661. For instance, 18 of 20 peptides designed according to these guidelines, containing 8-39 residues covering 75% of the sequence of the influenza virus hemagglutinin HAI polypeptide chain, induced antibodies that reacted with the HA1 protein or intact virus; and 12/12 peptides from the MuLV polymerase and 18/18 from the rabies glycoprotein induced antibodies that precipitated the respective proteins.

Antigenic epitope-bearing peptides and polypeptides of the invention are therefore useful to raise antibodies, including monoclonal antibodies, that bind specifically to a polypeptide of the invention. Thus, a high proportion of hybridomas obtained by fusion of spleen cells from donors immunized with an antigen epitope-bearing peptide generally secrete antibody reactive with the native protein. Sutcliffe et al., supra, at 663. The antibodies raised by antigenic epitope bearing peptides or polypeptides are useful to detect the mimicked protein, and antibodies to different

peptides may be used for tracking the fate of various regions of a protein precursor which undergoes posttranslation processing. The peptides and anti-peptide antibodies may be used in a variety of qualitative or quantitative assays for the mimicked protein, for instance in competition assays since it has been shown that even short peptides  
5 (e.g., about 9 amino acids) can bind and displace the larger peptides in immunoprecipitation assays. See, for instance, Wilson, I.A. et al., Cell 37:767-778 at 777 (1984). The anti-peptide antibodies of the invention also are useful for purification of the mimicked protein, for instance, by adsorption chromatography using methods well known in the art.

10                   Antigenic epitope-bearing peptides and polypeptides of the invention designed according to the above guidelines preferably contain a sequence of at least seven, more preferably at least nine and most preferably between about 15 to about 30 amino acids contained within the amino acid sequence of a polypeptide of the invention. However, peptides or polypeptides comprising a larger portion of an amino  
15 acid sequence of a polypeptide of the invention, containing about 30 to about 50 amino acids, or any length up to and including the entire amino acid sequence of a polypeptide of the invention, also are considered epitope-bearing peptides or polypeptides of the invention and also are useful for inducing antibodies that react with the mimicked protein. Preferably, the amino acid sequence of the epitope-bearing  
20 peptide is selected to provide substantial solubility in aqueous solvents (i.e., the sequence includes relatively hydrophilic residues and highly hydrophobic sequences are preferably avoided); and sequences containing proline residues are particularly preferred.

                  The epitope-bearing peptides and polypeptides of the invention may  
25 be produced by any conventional means for making peptides or polypeptides including recombinant means using nucleic acid molecules of the invention. For instance, a short epitope-bearing amino acid sequence may be fused to a larger polypeptide which acts as a carrier during recombinant production and purification, as well as during immunization to produce anti-peptide antibodies.

30                   Epitope-bearing peptides also may be synthesized using known methods of chemical synthesis. For instance, Houghten has described a simple method for synthesis of large numbers of peptides, such as 10-20 mg of 248 different 13 residue peptides representing single amino acid variants of a segment of the HAI polypeptide which were prepared and characterized (by ELISA-type binding studies) in  
35 less than four weeks. Houghten, R. A., Proc. Natl. Acad. Sci. USA 82:5131-5135 (1985). This "Simultaneous Multiple Peptide Synthesis (SMPS)" process is further

described in U.S. Patent No. 4,631,211 to Houghten et al. (1986). In this procedure the individual resins for the solid-phase synthesis of various peptides are contained in separate solvent-permeable packets, enabling the optimal use of the many identical repetitive steps involved in solid-phase methods.

5 A completely manual procedure allows 500-1000 or more syntheses to be conducted simultaneously. Houghten et al., *supra*, at 5134.

Epitope-bearing peptides and polypeptides of the invention are used to induce antibodies according to methods well known in the art. See, for instance, Sutcliffe et al., *supra*; Wilson et al., *supra*; Chow, M. et al., *Proc. Natl. Acad. Sci. USA* 10 82:910-914; and Bittle, F.J. et al., *J. Gen. Virol.* 66:2347-2354 (1985).

Generally, animals may be immunized with free peptide; however, anti-peptide antibody titer may be boosted by coupling of the peptide to a macromolecular carrier, such as keyhole limpet hemocyanin (KLH) or tetanus toxoid. For instance, peptides containing cysteine may be coupled to carrier using a linker 15 such as maleimidobenzoyl-N-hydroxysuccinimide ester (MBS), while other peptides may be coupled to carrier using a more general linking agent such as glutaraldehyde.

Animals such as rabbits, rats and mice are immunized with either free or carriercoupled peptides, for instance, by intraperitoneal and/or intradermal injection of emulsions containing about 100 ug peptide or carrier protein and Freund's adjuvant. 20 Several booster injections may be needed, for instance, at intervals of about two weeks, to provide a useful titer of anti-peptide antibody which can be detected, for example, by ELISA assay using free peptide adsorbed to a solid surface. The titer of anti-peptide antibodies in serum from an immunized animal may be increased by selection of anti-peptide antibodies, for instance, by adsorption to the peptide on a solid 25 support and elution of the selected antibodies according to methods well known in the art.

Immunogenic epitope-bearing peptides of the invention, i.e., those parts of a protein that elicit an antibody response when the whole protein is the immunogen, are identified according to methods known in the art. For instance, 30 Geysen et al., 1984, *supra*, discloses a procedure for rapid concurrent synthesis on solid supports of hundreds of peptides of sufficient purity to react in an enzyme-linked immunosorbent assay. Interaction of synthesized peptides with antibodies is then easily detected without removing them from the support. In this manner a peptide bearing an immunogenic epitope of a desired protein may be identified routinely by one 35 of ordinary skill in the art. For instance, the immunologically important epitope in the coat protein of foot-and-mouth disease virus was located by Geysen et al. with a

resolution of seven amino acids by synthesis of an overlapping set of all 208 possible hexapeptides covering the entire 213 amino acid sequence of the protein. Then, a complete replacement set of peptides in which all 20 amino acids were substituted in turn at every position within the epitope were synthesized, and the particular amino acids conferring specificity for the reaction with antibody were determined. Thus, peptide analogs of the epitope-bearing peptides of the invention can be made routinely by this method. U.S. Patent No. 4,708,781 to Geysen (1987) further describes this method of identifying a peptide bearing an immunogenic epitope of a desired protein.

Further still, U.S. Patent No. 5,194,392 to Geysen (1990) describes a general method of detecting or determining the sequence of monomers (amino acids or other compounds) which is a topological equivalent of the epitope (i.e., a "mimotope") which is complementary to a particular paratope (antigen binding site) of an antibody of interest. More generally, U.S. Patent No. 4,433,092 to Geysen (1989) describes a method of detecting or determining a sequence of monomers which is a topographical equivalent of a ligand which is complementary to the ligand binding site of a particular receptor of interest. Similarly, U.S. Patent No. 5,480,971 to Houghten, R. A. et al. (1996) on Peralkylated Oligopeptide Mixtures discloses linear C1-C7-alkyl peralkylated oligopeptides and sets and libraries of such peptides, as well as methods for using such oligopeptide sets and libraries for determining the sequence of a peralkylated oligopeptide that preferentially binds to an acceptor molecule of interest. Thus, non-peptide analogs of the epitope-bearing peptides of the invention also can be made routinely by these methods.

#### **Use of NBE 038 baking enzymes in industrial processes**

The invention also relates to the use of the NBE 038 baking enzyme according to the invention in a selected number of industrial processes. Despite the long term experience obtained with these processes, the baking enzyme according to the invention features a number of significant advantages over the enzymes currently used. Depending on the specific application, these advantages can include aspects like lower production costs, higher specificity towards the substrate, less antigenic, less undesirable side activities, higher yields when produced in a suitable microorganism, more suitable pH and temperature ranges, better tastes of the final product as well as food grade and kosher aspects.

CLAIMS

1. An isolated polynucleotide hybridisable to a polynucleotide according to SEQ ID NO:1 or SEQ ID NO: 2.
- 5 2. An isolated polynucleotide according to claim 1 hybridisable under high stringency conditions to a polynucleotide according to SEQ ID NO:1 or SEQ ID NO: 2.
3. An isolated polynucleotide according to claims 1 or 2 obtainable from a filamentous fungus.
- 10 4. An isolated polynucleotide according to claim 3 obtainable from *A. niger*.
5. An isolated polynucleotide encoding a polypeptide comprising an amino acid sequence according to SEQ ID NO: 3 or functional equivalents thereof.
6. An isolated polynucleotide encoding at least one functional domain of a polypeptide according to SEQ ID NO: 3 or functional equivalents thereof.
- 15 7. An isolated polynucleotide comprising a nucleotide sequence according to SEQ ID NO: 1 or SEQ ID NO: 2 or functional equivalents thereof.
8. An isolated polynucleotide according to SEQ ID NO: 1 or SEQ ID NO: 2.
9. A vector comprising a polynucleotide sequence according to claims 1 to 8.
- 20 10. A vector according to claim 9 wherein said polynucleotide sequence according to claims 1 to 8 is operatively linked with regulatory sequences suitable for expression of said polynucleotide sequence in a suitable host cell.
11. A vector according to claim 10 wherein said suitable host cell is a filamentous fungus.
- 25 12. A method for manufacturing a polynucleotide according to claims 1 – 8 or a vector according to claims 9 to 11 comprising the steps of culturing a host cell transformed with said polynucleotide or said vector and isolating said polynucleotide or said vector from said host cell.
13. An isolated polypeptide according to SEQ ID NO: 3 or functional equivalents

thereof.

14. An isolated polypeptide according to claim 13 obtainable from *Aspergillus niger*.
- 5 15. An isolated polypeptide obtainable by expressing a polynucleotide according to claims 1 to 8 or a vector according to claims 9 to 11 in an appropriate host cell, e.g. *Aspergillus niger*.
16. Recombinant baking enzyme comprising a functional domain of a NBE 038 polypeptide.
- 10 17. A method for manufacturing a polypeptide according to claims 13 to 16 comprising the steps of transforming a suitable host cell with an isolated polynucleotide according to claims 1 to 8 or a vector according to claims 9 to 11, culturing said cell under conditions allowing expression of said polynucleotide and optionally purifying the encoded polypeptide from said cell or culture medium.
- 15 18. A recombinant host cell comprising a polynucleotide according to claims 1 to 8 or a vector according to claims 9 to 11.
19. A recombinant host cell expressing a polypeptide according to claims 13 to 16.
20. Purified antibodies reactive with a polypeptide according to claims 13 to 16.
21. Fusion protein comprising a polypeptide sequence according to claims 13 to 16.



ABSTRACT

The invention relates to a newly identified polynucleotide sequence comprising a gene that encodes a novel baking enzyme. The invention features the full length nucleotide sequence of the novel gene, the cDNA sequence comprising the full  
5 length coding sequence of the novel baking enzyme as well as the amino acid sequence of the full-length functional protein and functional equivalents thereof. The invention also relates to methods of using these enzymes in industrial processes and methods of diagnosing fungal infections. Also included in the invention are cells transformed with a polynucleotide according to the invention and cells wherein a baking  
10 enzyme according to the invention is genetically modified to enhance its activity and/or level of expression.

# SEQUENCE LISTING

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gac	gac	tgg	tat	tgg	acc	gac	gta	gtc	tcc	gaa	gat	tgt	ctc	gct	ctc		336
Asp	Asp	Trp	Tyr	Trp	Thr	Asp	Val	Val	Ser	Glu	Asp	Cys	Leu	Ala	Leu		
			100					105					110				
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Ser	Val	Ile	Arg	Pro	His	Gly	Ile	Asp	Ser	Ser	Ala	Lys	Leu	Pro	Val		
		115					120					125					
gtc	ttc	tgg	atg	cat	ggg	gga	gaa	ttc	gca	gaa	gga	ggc	act	cgc	gac		432
Val	Phe	Trp	Met	His	Gly	Gly	Glu	Phe	Ala	Glu	Gly	Gly	Thr	Arg	Asp		
		130				135						140					
tcc	cgt	tac	aac	ctc	tcc	tac	atc	gtc	caa	caa	tcc	cag	gag	atg	caa		480
Ser	Arg	Tyr	Asn	Leu	Ser	Tyr	Ile	Val	Gln	Gln	Ser	Gln	Glu	Met	Gln		
				150						155					160		
tct	ccc	atc	att	ggc	gtg	act	gtc	aac	tac	cgc	ctt	tcg	gga	tgg	gga		528
Ser	Pro	Ile	Ile	Gly	Val	Thr	Val	Asn	Tyr	Arg	Leu	Ser	Gly	Trp	Gly		
				165				170						175			
ttc	ctc	tat	agc	cag	gaa	gtc	gcc	gac	gaa	ggc	tcc	gcc	aac	tta	gga		576
Phe	Leu	Tyr	Ser	Gln	Glu	Val	Ala	Asp	Glu	Gly	Ser	Ala	Asn	Leu	Gly		
			180					185					190				
ctc	cgc	gac	caa	cgg	cac	gct	ctg	tac	tgg	ctc	caa	gag	aat	atc	gct		624
Leu	Arg	Asp	Gln	Arg	His	Ala	Leu	Tyr	Trp	Leu	Gln	Glu	Asn	Ile	Ala		
		195					200					205					
tcc	ttc	ggc	ggc	gac	ccg	tcg	cgg	ctc	acc	atc	tgg	ggc	caa	agt	gcc		672
Ser	Phe	Gly	Gly	Asp	Pro	Ser	Arg	Leu	Thr	Ile	Trp	Gly	Gln	Ser	Ala		
		210				215					220						
ggg	gcc	aac	agc	gtc	ggg	ctc	cat	tta	gtg	gca	tac	gac	ggc	cag	aat		720
Gly	Ala	Asn	Ser	Val	Gly	Leu	His	Leu	Val	Ala	Tyr	Asp	Gly	Gln	Asn		
				230					235						240		
gat	ggc	atc	ttc	cgt	gcc	ggg	atc	gcc	gag	agc	ggc	tcc	gta	ccc	tcc		768
Asp	Gly	Ile	Phe	Arg	Ala	Gly	Ile	Ala	Glu	Ser	Gly	Ser	Val	Pro	Ser		
				245				250						255			
ctc	gca	gca	tac	atg	agc	gcc	gaa	gat	gca	caa	cca	tac	tat	gat	gcc		816
Leu	Ala	Ala	Tyr	Met	Ser	Ala	Glu	Asp	Ala	Gln	Pro	Tyr	Tyr	Asp	Ala		
			260					265					270				
gtc	gtc	aac	gca	acc	aac	tgc	acc	ggc	tct	tcc	aac	acc	ctt	act	tgt		864
Val	Val	Asn	Ala	Thr	Asn	Cys	Thr	Gly	Ser	Ser	Asn	Thr	Leu	Thr	Cys		
		275					280					285					
ctc	cgt	gaa	gtt	ccc	acc	gac	gtc	ctc	agc	tcc	atc	ttc	aac	agc	tcc		912
Leu	Arg	Glu	Val	Pro	Thr	Asp	Val	Leu	Ser	Ser	Ile	Phe	Asn	Ser	Ser		
		290				295					300						
ctc	gtc	gct	ggg	gca	gga	tat	cat	ccc	gtc	att	gac	ggc	gat	ttc	ctc		960
Leu	Val	Ala	Gly	Ala	Gly	Tyr	His	Pro	Val	Ile	Asp	Gly	Asp	Phe	Leu		
		305			310				315						320		
aga	gcc	tcg	ggg	ata	gtt	aat	ctc	cag	act	ggc	caa	ttc	gcc	aaa	acc		1008
Arg	Ala	Ser	Gly	Ile	Val	Asn	Leu	Gln	Thr	Gly	Gln	Phe	Ala	Lys	Thr		
			325					330					335				
ccg	ctt	ctt	atc	ggc	acc	aac	ttc	gac	gaa	ggg	acc	aag	tat	gcc	cct		1056
Pro	Leu	Leu	Ile	Gly	Thr	Asn	Phe	Asp	Glu	Gly	Thr	Lys	Tyr	Ala	Pro		
			340					345					350				
cat	ggc	tat	aat	acc	acc	gac	caa	ttt	gtc	tcc	ctc	gtc	caa	gcc	aac		1104
His	Gly	Tyr	Asn	Thr	Thr	Asp	Gln	Phe	Val	Ser	Leu	Val	Gln	Ala	Asn		
		355				360						365					
gga	acc	aat	tat	acc	agc	gct	ctc	acc	att	gca	tcc	ctg	tac	cca	gat		1152
Gly	Thr	Asn	Tyr	Thr	Ser	Ala	Leu	Thr	Ile	Ala	Ser	Leu	Tyr	Pro	Asp		
		370				375					380						
gac	cca	gcc	gtt	ggg	att	ccg	gga	acc	ctt	caa	ggg	cgt	ccc	cca	ccg		1200
Asp	Pro	Ala	Val	Gly	Ile	Pro	Gly	Thr	Leu	Gln	Gly	Arg	Pro	Pro	Pro		

385				390				395				400				
tca	tac	ggt	tac	cag	tgg	aag	cgc	gtg	gct	gcc	ttc	ctc	ggc	gat	ctg	1248
Ser	Tyr	Gly	Tyr	Gln	Trp	Lys	Arg	Val	Ala	Ala	Phe	Leu	Gly	Asp	Leu	
405				410				415								
ctc	atg	cac	gcg	cct	cgc	cgc	gtg	aca	acc	cag	tgg	ctg	gca	cac	tgg	1296
Leu	Met	His	Ala	Pro	Arg	Arg	Val	Thr	Thr	Gln	Trp	Leu	Ala	His	Trp	
420				425				430								
aat	gta	cct	gcc	tac	gtg	tat	cac	tgg	aac	gtg	atg	aca	cta	ggg	cca	1344
Asn	Val	Pro	Ala	Tyr	Val	Tyr	His	Trp	Asn	Val	Met	Thr	Leu	Gly	Pro	
435				440				445								
tta	gat	gga	gcc	gcg	cat	ggc	tat	gaa	gtc	ccc	ttc	agt	ttc	cat	aat	1392
Leu	Asp	Gly	Ala	Ala	His	Gly	Tyr	Glu	Val	Pro	Phe	Ser	Phe	His	Asn	
450				455				460								
tat	gat	ggt	ttg	ggc	gat	gaa	cgg	gga	aac	gac	agc	gtg	acc	tgg	cca	1440
Tyr	Asp	Gly	Leu	Gly	Asp	Glu	Arg	Gly	Asn	Asp	Ser	Val	Thr	Trp	Pro	
465				470				475				480				
caa	cta	tcg	act	atg	atg	tca	cgg	atg	tgg	gtg	agc	ttt	att	aat	cat	1488
Gln	Leu	Ser	Thr	Met	Met	Ser	Arg	Met	Trp	Val	Ser	Phe	Ile	Asn	His	
485				490				495								
ttg	gat	ccg	aat	tat	agt	aat	agt	gag	tga							1518
Leu	Asp	Pro	Asn	Tyr	Ser	Asn	Ser	Glu								
500				505												

<400>	3															
Met	Ala	Ser	Ser	Val	Phe	Leu	Pro	Leu	Leu	Ala	Ala	Ser	Leu	Leu	Pro	
1				5					10					15		
Thr	Leu	Ala	Ser	Thr	Gln	Asn	Ala	Asp	Thr	Pro	Thr	Ser	Ala	Pro	Thr	
			20					25					30			
Val	Gln	Val	Arg	Asn	Gly	Thr	Tyr	Glu	Gly	Leu	Tyr	Asn	Pro	Thr	Tyr	
		35					40					45				
Asn	Gln	Asp	Leu	Phe	Leu	Gly	Ile	Pro	Tyr	Ala	Gln	Pro	Pro	Val	Gly	
	50					55					60					
Glu	Leu	Arg	Phe	Arg	Pro	Pro	Gln	Pro	Leu	Asn	Thr	Thr	Trp	Thr	Gly	
65				70						75					80	
Thr	Arg	Asn	Ala	Thr	Ala	Tyr	Tyr	Asn	Glu	Cys	Ile	Gly	Tyr	Gly	Ser	
				85					90					95		
Asp	Asp	Trp	Tyr	Trp	Thr	Asp	Val	Val	Ser	Glu	Asp	Cys	Leu	Ala	Leu	
			100					105					110			
Ser	Val	Ile	Arg	Pro	His	Gly	Ile	Asp	Ser	Ser	Ala	Lys	Leu	Pro	Val	
		115					120					125				
Val	Phe	Trp	Met	His	Gly	Gly	Glu	Phe	Ala	Glu	Gly	Gly	Thr	Arg	Asp	
	130					135					140					
Ser	Arg	Tyr	Asn	Leu	Ser	Tyr	Ile	Val	Gln	Gln	Ser	Gln	Glu	Met	Gln	
145				150						155					160	
Ser	Pro	Ile	Ile	Gly	Val	Thr	Val	Asn	Tyr	Arg	Leu	Ser	Gly	Trp	Gly	
				165					170					175		
Phe	Leu	Tyr	Ser	Gln	Glu	Val	Ala	Asp	Glu	Gly	Ser	Ala	Asn	Leu	Gly	
			180					185					190			
Leu	Arg	Asp	Gln	Arg	His	Ala	Leu	Tyr	Trp	Leu	Gln	Glu	Asn	Ile	Ala	
		195					200					205				
Ser	Phe	Gly	Gly	Asp	Pro	Ser	Arg	Leu	Thr	Ile	Trp	Gly	Gln	Ser	Ala	

210		215		220
Gly Ala Asn Ser Val	Gly Leu His Leu Val	Ala Tyr Asp Gly Gln Asn		
225	230	235		240
Asp Gly Ile Phe Arg	Ala Gly Ile Ala Glu	Ser Gly Ser Val Pro Ser		
	245	250		255
Leu Ala Ala Tyr Met	Ser Ala Glu Asp Ala	Gln Pro Tyr Tyr Asp Ala		
	260	265		270
Val Val Asn Ala Thr	Asn Cys Thr Gly Ser	Ser Asn Thr Leu Thr Cys		
	275	280		285
Leu Arg Glu Val Pro	Thr Asp Val Leu Ser	Ser Ile Phe Asn Ser Ser		
	290	295		300
Leu Val Ala Gly Ala	Gly Tyr His Pro Val	Ile Asp Gly Asp Phe Leu		
305	310	315		320
Arg Ala Ser Gly Ile	Val Asn Leu Gln Thr	Gly Gln Phe Ala Lys Thr		
	325	330		335
Pro Leu Leu Ile Gly	Thr Asn Phe Asp Glu	Gly Thr Lys Tyr Ala Pro		
	340	345		350
His Gly Tyr Asn Thr	Thr Asp Gln Phe Val	Ser Leu Val Gln Ala Asn		
	355	360		365
Gly Thr Asn Tyr Thr	Ser Ala Leu Thr Ile	Ala Ser Leu Tyr Pro Asp		
	370	375		380
Asp Pro Ala Val Gly	Ile Pro Gly Thr Leu	Gln Gly Arg Pro Pro Pro		
385	390	395		400
Ser Tyr Gly Tyr Gln	Trp Lys Arg Val Ala	Ala Phe Leu Gly Asp Leu		
	405	410		415
Leu Met His Ala Pro	Arg Arg Val Thr Thr	Gln Trp Leu Ala His Trp		
	420	425		430
Asn Val Pro Ala Tyr	Val Tyr His Trp Asn	Val Met Thr Leu Gly Pro		
	435	440		445
Leu Asp Gly Ala Ala	His Gly Tyr Glu Val	Pro Phe Ser Phe His Asn		
	450	455		460
Tyr Asp Gly Leu Gly	Asp Glu Arg Gly Asn	Asp Ser Val Thr Trp Pro		
465	470	475		480
Gln Leu Ser Thr Met	Met Ser Arg Met Trp	Val Ser Phe Ile Asn His		
	485	490		495
Leu Asp Pro Asn Tyr	Ser Asn Ser Glu			
	500	505		